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JC881 U.S. PTO 08/31/00

UTILITY PATENT APPLICATION TRANSMITTAL UNDER 37 CFR 1.53(b)	ATTORNEY DOCKET 81229RLO Customer No. 01333
To: Commissioner for Patents Box Patent Application Washington, D.C. 20231	**Express Mail Label No.** **EL485198656US**
DETECTING HOPPING PIXEL DEFECTS IN CCD IMAGE SENSORS First Named Inventor (or Application Identifier): Shen Wang, et al	**Date:** 8.31.00

JC564 U.S. PTO 09/652316 08/31/00

Enclosed are:

1. [X] Specification
2. [11] Sheet(s) of drawing(s)
3. [ ] Information Disclosure Statement Under 37 CFR 1.97.
4. Combined Declaration for Patent Application and Power of Attorney:
   - 4a. [X] New
   - 4b. [ ] Copy from a prior application (37 CFR 1.63(d) (for continuation/divisional with Box 11 completed)
5. [ ] Incorporation by Reference (useable if Box 4b is checked) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [X] Assignment of the invention to **Eastman Kodak Company**
7. [ ] Certified copy of a priority
8. [ ] Associate Power of Attorney
9. [ ] Deletion of Inventor(s). Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

10. [ ] If a 111A application prior to examination of the above-identified application, amend the specification at Page 1, after the title, by inserting the following:
--CROSS REFERENCE TO RELATED APPLICATION
Reference is made to and priority claimed from U.S. Provisional Application Serial No. , filed , entitled .

If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

11. [ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ,

12. [X] Please address all written communications to Thomas H. Close, Patent Legal Staff, Eastman Kodak Company, 343 State Street, Rochester, NY 14650-2201.
Please Direct all telephone calls to Raymond L. Owens at (716) 477-4653.

The filing fee has been calculated as shown below:

FOR:	NO. FILED		NO. EXTRA	RATE	FEE
BASIC FEE					$ 690
TOTAL CLAIMS	5	- 20 =	0	x 18 =	$ 0
INDEPENDENT CLAIMS	1	- 3 =	0	x 78 =	$ 0
[ ] MULTIPLE DEPENDENT CLAIM PRESENTED				+ 260	$0
				TOTAL	$ 690

[X] Please charge my Eastman Kodak Company Deposit Account No. **05-0225** in the amount of $ 690.

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[X] The Commissioner is hereby authorized to charge any additional filing fees required under 37 CFR 1.16 or credit any overpayment to Eastman Kodak Company Deposit Account No. **05-0225**.

A duplicate copy of this sheet is enclosed.

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ORIGINAL PATENT APPLICATION BASED ON:

Docket: **81229RLO**

Inventor(s): **Shen Wang**

Thomas Carducci

Attorney: **Raymond L. Owens**

DETECTING HOPPING PIXEL DEFECTS IN CCD IMAGE SENSORS

EXPRESS MAIL LABEL NO.: EL485198656US

Date of Mailing: 8-31-00

DETECTING HOPPING PIXEL DEFECTS IN CCD IMAGE SENSORS

FIELD OF THE INVENTION

This invention relates to detecting hopping pixel defects in CCD image sensors.

BACKGROUND OF THE INVENTION

Image sensors typically are in the form of linear and area image sensors. These sensors are often provided by charge coupled devices (CCDs). Area image sensors can take the form of interline image sensors and full frame image sensors. There are a number of defects which affect image quality in image sensors. Of particular concern is a hopping pixel defect. This defect often comes up in a random fashion and so unless it is detected in an image sensor through manufacturing quality control, the image sensor will be delivered to the general public and have this defect. A hopping pixel defect is defined as a pixel whose dark signal level varies beyond the random noise along with the time.

FIG. 1a depicts a series of test for an individual pixel in an image sensor in which the output from the series of test is plotted as signal level versus time. FIG. 1a also illustrates a representative output for a particular pixel that does not have a hopping pixel defect. FIG. 1b depicts a histogram for the data of the pixel shown in FIG. 1a which is a plot of the counts or frequency versus signal level. It shows that the normal dark signal obeys a Gaussian distribution and it has only one peak which means the pixel has only one signal level. FIGS. 1c and 1d show similar plots to those respectively in FIGS. 1a and 1b, but in this case an individual pixel has a hopping pixel defect. In FIG. 1d the hopping pixel has two peaks which represent two different signal levels. One is the normal dark signal level (about 372 counts) and the other one is the hopping signal level (about 386 counts). In this case, 8 counts equal to 1 millivolt. Therefore, the hopping magnitude is about 1.75 millivolt.

Heretofore it has been difficult to detect such defects. The difficulty of the task is that the hopping pixel signal is very small (almost down to a couple of millivolts, close to the test system noise level) and hopping rate is random (some defects may hop once per milliseconds and others may take minutes or even hours to hop once).

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a test method for effectively detecting hopping pixel defects in an image sensor.

It has been discovered that the hopping magnitude and hopping rate increase with the increase of the temperature. The present invention makes use of a heated environment to detect hopping pixel defects in an image sensor.

This object is achieved by a method for detecting if there are any temperature dependent hopping pixel defects in an image sensor, comprising the steps of:

(a) providing an image sensor in a heated environment having a temperature selected such that hopping pixel defects can be detected; and

(b) testing the image sensor and analyzing the output of the pixels of the image sensor to determine if there are any hopping pixel defects.

It is a feature of the present invention that by testing an image sensor at higher temperature allows an amplification of a defect's signature, namely its hopping magnitude and hopping rate, so that small defect signal which is usually hidden in the system noise at ambient temperature can be detected.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1a and 1b depict graphs previously described for a particular pixel in an image sensor which does not have a hopping pixel defect;

FIGS. 1c and 1d depict graphs previously described for a particular pixel in an image sensor which does have a hopping pixel defect;

FIG. 2 depicts a representative test system for detecting for hopping pixel defects;

FIG. 3 shows a flowchart of a test algorithm in the system of FIG. 2 to determine if there are any hopping pixel defects in an image sensor being tested in FIG. 2; and

FIGS. 4a-e depict the output of various stages in the operation of the system of FIG. 2 and corresponding to positions in FIG. 3.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1a-1d are comparisons of dark signal levels and their histograms between a good pixel and a hopping pixel which have already been discussed in Background of the Invention section.

FIG. 2 is a representative diagram showing a test system for detecting hopping pixel defects in image sensors. A CCD image sensor 10 is seated on a heat plate 12 of which temperature is controlled by a temperature control unit 14. The temperature

of the plate 12 is typically adjusted so that the CCD image sensor 10 when operated will be at temperature in the range of about 20 to 80°C. As previously discussed, it has been determined that by heating the CCD image sensor 10 under test, the hopping pixel defects will become more pronounced and occur more frequently. The system has power supplies and pulse generating circuits 32 controlled by a central processing unit (CPU) 20 to support CCD DC bias and clock driver circuits 34. The clock driver circuits 34 operates the CCD in a well known fashion under the control of the pulse generating circuits 32. The CCD output signals are digitized and synchronized to display results on output device 48 (commonly a cathode ray tube (CRT)) through an A/D converter 42, a frame grabber 44 and its internal memory 46. A test algorithm 22 (will be discussed later) is fed into the CPU 20 at the beginning of the test and the CPU 20 controls the operating conditions of the CCD image sensor 10 and starts the test. The CPU 20 calculates the test results in its internal memory 46 according to the test algorithm 22 and sends the final results to output device 48. The test is finished by mapping detected hopping pixel defects in the CCD image sensor 10 to the output device 46. See FIGS. 4a-e.

FIG. 3 depicts a flowchart of a test algorithm for operating the system of FIG. 2 to detect hopping pixel defects. When a test of a CCD image sensor 10 (FIG. 2) starts in block 51, a CPU 20 (FIG. 2) is initialized in block 52. Next in block 53 the CPU 20 (FIG. 2) operates the system of FIG. 2 so that a number of frames (X) of output signals are captured. These output signals for each pixel are averaged and then stored in an internal memory 46 (FIG. 2). FIG. 4a shows an eight count-averaged output signals for the first cycle of the pixel in a 1K linear CCD image sensor 10 being tested at 40 °C. This capturing process repeats for a certain number of cycles (Y) which is predefined at the beginning of the test showing in block 55. FIG. 4b is the output signal of the 30^{th} count cycle. In this chart, there are two pixels which have signal levels significantly higher than the normal level. For each count cycle, the CPU 20 (FIG. 2) then updates the output signals in block 54 so as to store the maximum and minimum pixel values captured in the CCD image sensor 10 (FIG. 2). FIGS. 4c and 4d show the maximum and minimum pixel values captured during the Y cycles in the CCD image sensor 10 (FIG. 2).

In block 56 the CPU 20 (FIG. 2) subtracts the maximum from the minimum values for all pixels and gets the difference hereinafter referred to as Delts(I) (I is the index of pixels). Also FIG. 4e shows the signal level of Delts(I). Comparing Delts(I) with a predefined threshold determines if a pixel has a potential hopping pixel defect as shown in block 57. If the Delts(I) is larger than the threshold, the pixel I is called a potential hopping pixel. FIG. 4e show pixels 15 and 300 have potential hopping pixel defects. Also in block 57 the CPU 20 (FIG. 2) records the occurrence of those pixels being marked as potential hopping pixels. Therefore, in this pixel 15 and 300 are each recorded as one occurrence of potential hopping pixels.

Sometimes during the test, burst noise can be randomly generated from other sources such as electronic circuitry such as CPU 20 malfunction other than the CCD image sensor 10 itself. It is important to take this noise into account. Therefore, usually the above test repeats for a couple of loops (Z) showing in block 58. In each loop for all pixels, the CPU 20 records the occurrences of their being caught as potential hopping pixels. Only those pixels with occurrences greater than a predefined value (T) are finally marked as hopping pixels. The process is shown in blocks 59 and 60. Block 61 represents the end of the test. For example, if Z equals 2, it means the whole test repeats twice. In the second test loop, pixel 15 is recorded again as a potential hopping pixel, but not pixel 300. If the predefine value T is 1, it means only those pixels whose occurrences being recorded as potential hopping pixels are greater than 1 are finally reported as hopping pixels. In this case, only pixel 15 is reported as a hopping pixel but not pixel 300 since pixel 300 is only recorded once and pixel 15 is recorded twice.

Depending on the noise performance of the test system showing in FIG. 2, the number of X-frame-average can be varied. Typically X equals from 4 to 16. Another parameter, the repeated cycle Y, is determined by the sensor's application such as the maximum duration time of the CCD image sensor 10's single task, the quality factor and the cost. The larger Y, the longer time the sensor being tested and the better chance to capture the defective parts, but in higher cost. Also the numbers of Z and T can be varied with different applications. The threshold of determining if a pixel has a hopping defect mainly depends on customer's applications. It is usually much lower in the high-end applications than in the low-end applications.

A typical setting in the test system shown in FIG. 2 is as follows. At temperature Temp=40 °C, X=8, Y=50, Z=5, T=3.

FIGS. 4a-4e have already been described in this section which show the output profiles in different test stages in blocks 53, 54 and 56 (FIG. 3). These outputs can, of course, be visually produced by output device 48.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

10	image sensor
12	heat plate
14	temperature control unit
15	hopping pixel
20	central processing unit
22	test algorithm
32	pulse generating circuits
34	clock driver circuits
42	A/D converter
44	frame grabber
46	internal memory
48	output device
51	block
52	block
53	block
54	block
55	block
56	block
57	block
58	block
59	block
60	block
61	block
300	hopping pixel

WHAT IS CLAIMED IS:

1. A method for determining if there is a temperature dependent hopping pixel defect in an image sensor, comprising the steps of:

(a) providing an image sensor in a heated environment having a temperature selected such that hopping pixel defects can be detected; and

(b) operating the image sensor and analyzing the output of the pixels of the image sensor to determine if there are hopping pixel defects.

2. The method of claim 1 wherein step (b) further includes capturing the output signals in a voltage format provided by the pixels a number of times and determining if there are hopping pixel defects in the output signals.

3. The method of claim 2 processing the output signals to produce a visual display which designates the pixels which have hopping pixel defects and the relative amplitude of such defects.

4. The method of claim 2 wherein the image sensor is a linear or area sensor.

5. The method of claim 2 processing the output signals to produce a visual display which designates the pixels which have hopping pixel defects and the relative amplitude of such defects.

ABSTRACT OF THE DISCLOSURE

A method for determining if there is a temperature dependent hopping pixel defect in an image sensor, including the steps of providing an image sensor in a heated environment having a temperature selected such that hopping pixel defects can be detected; and operating the image sensor and analyzing the output of the pixels of the image sensor to determine if there are hopping pixel defects.

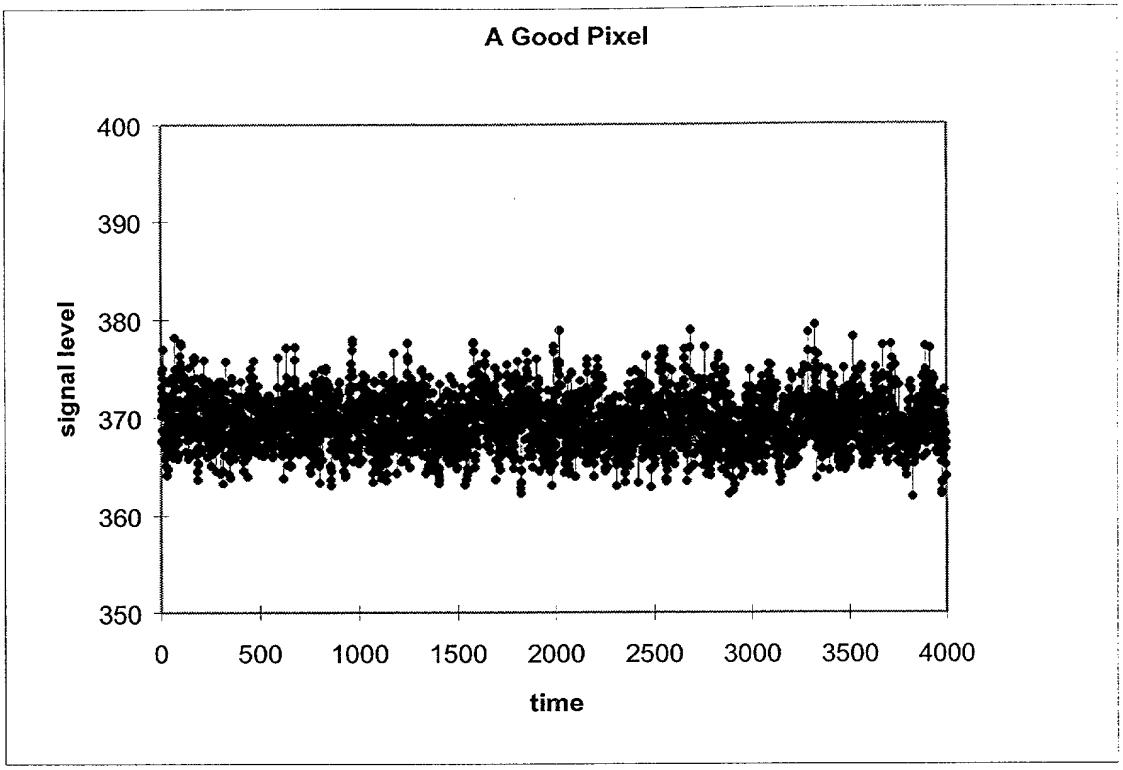
A Good Pixel
signal level
400
390
380
370
360
350
0
500
1000
1500
2000
2500
3000
3500
4000
time

FIG. 1a

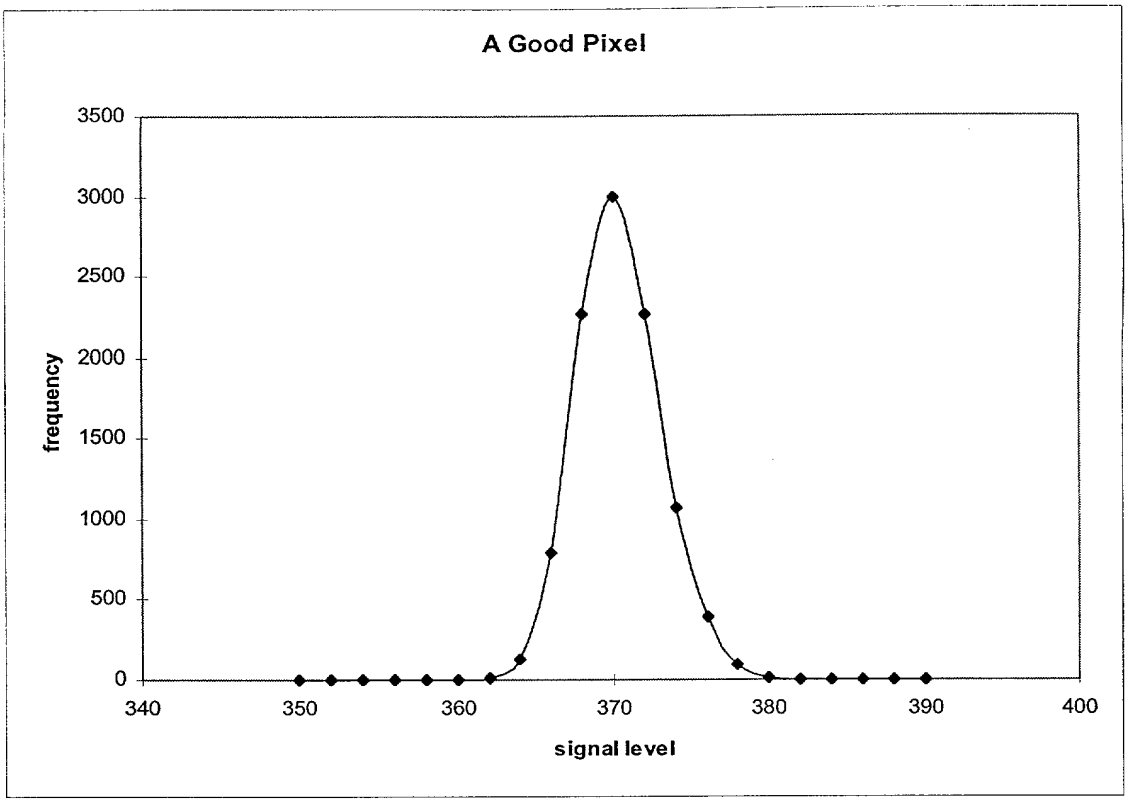
A Good Pixel
3500
3000
2500
2000
1500
1000
500
0
frequency
340
350
360
370
380
390
400
signal level

FIG. 1b

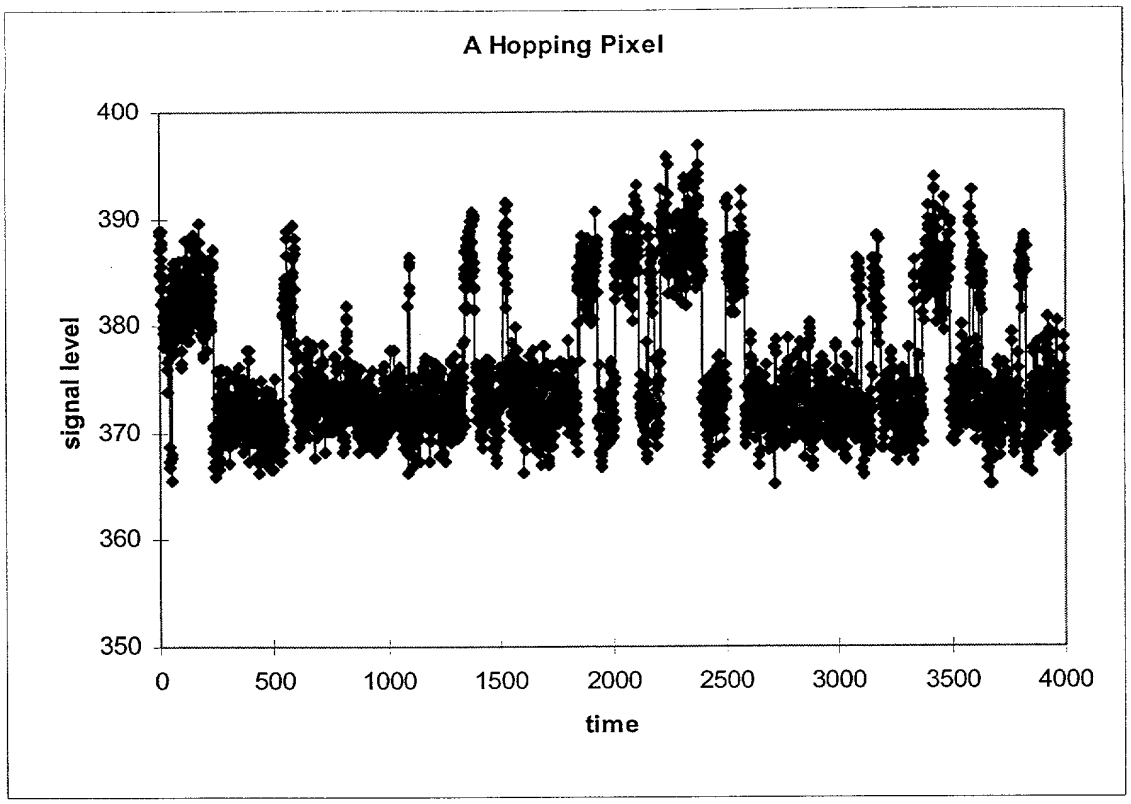
A Hopping Pixel
400
390
380
370
360
350
signal level
0
500
1000
1500
2000
2500
3000
3500
4000
time

FIG. 1c

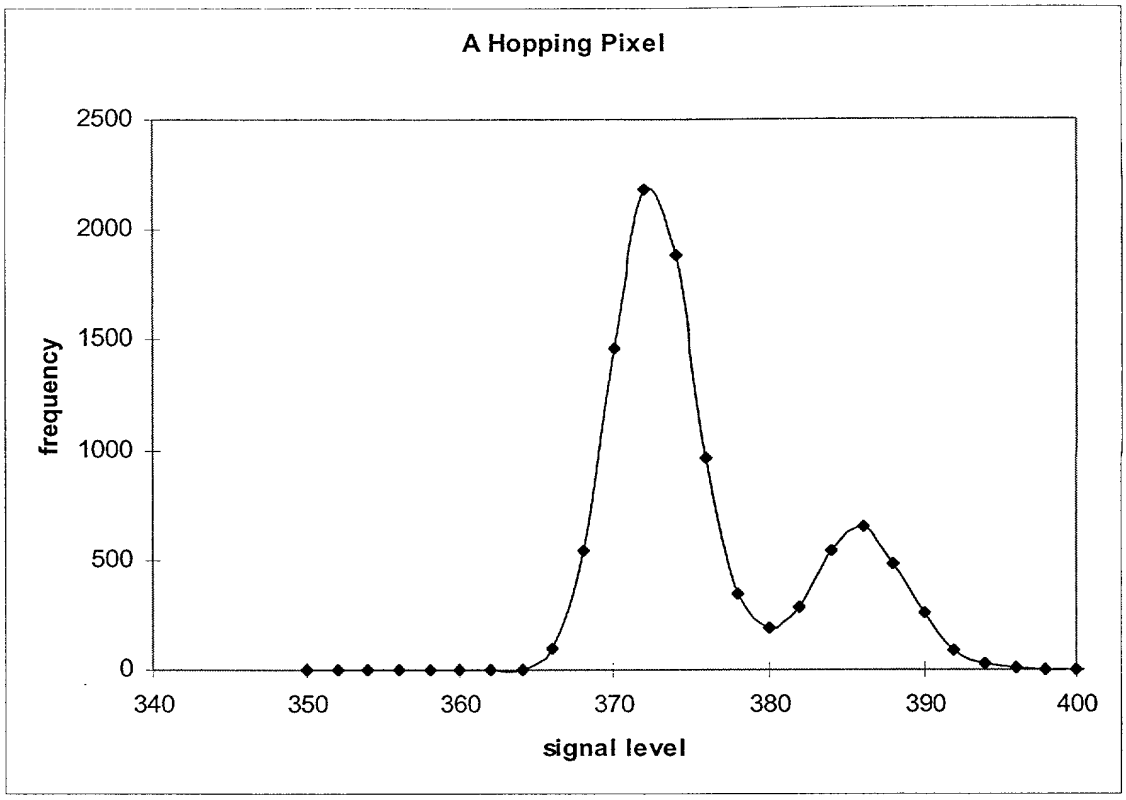
A Hopping Pixel
2500
2000
1500
1000
500
0
frequency
340
350
360
370
380
390
400
signal level

FIG. 1d

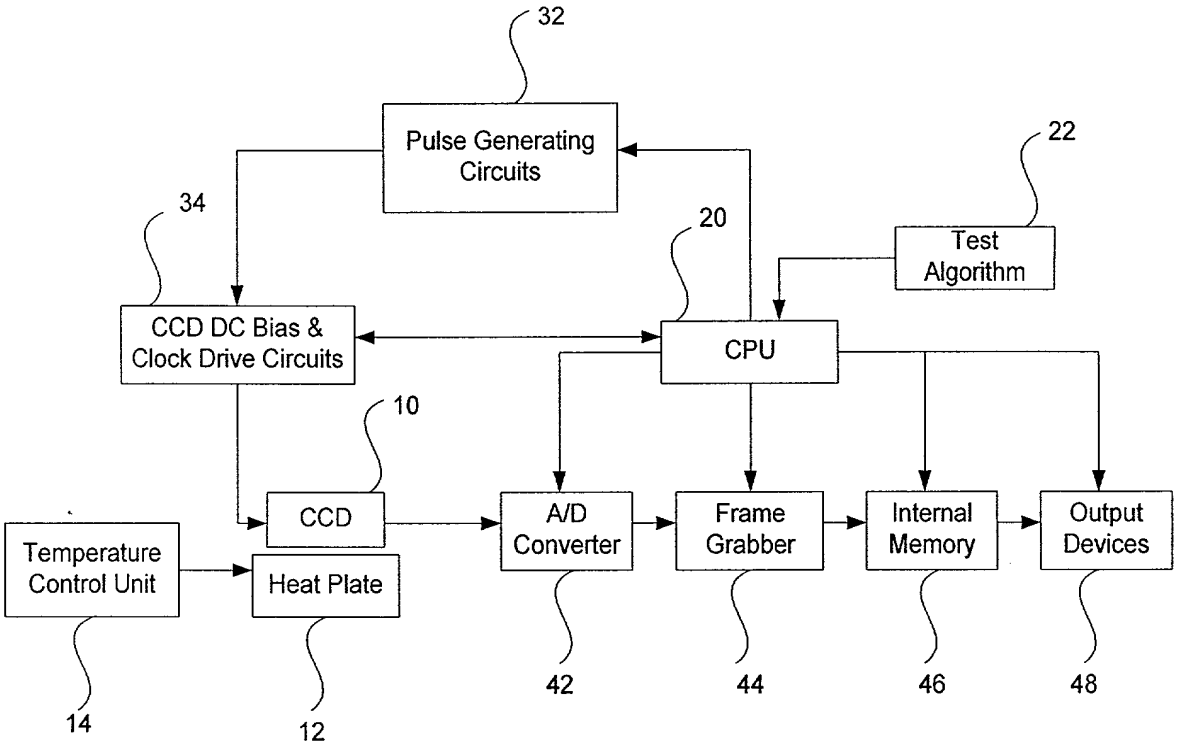
32
Pulse Generating Circuits
22
34
20
Test Algorithm
CCD DC Bias & Clock Drive Circuits
CPU
10
CCD
A/D Converter
Frame Grabber
Internal Memory
Output Devices
Temperature Control Unit
Heat Plate
14
12
42
44
46
48

FIG. 2

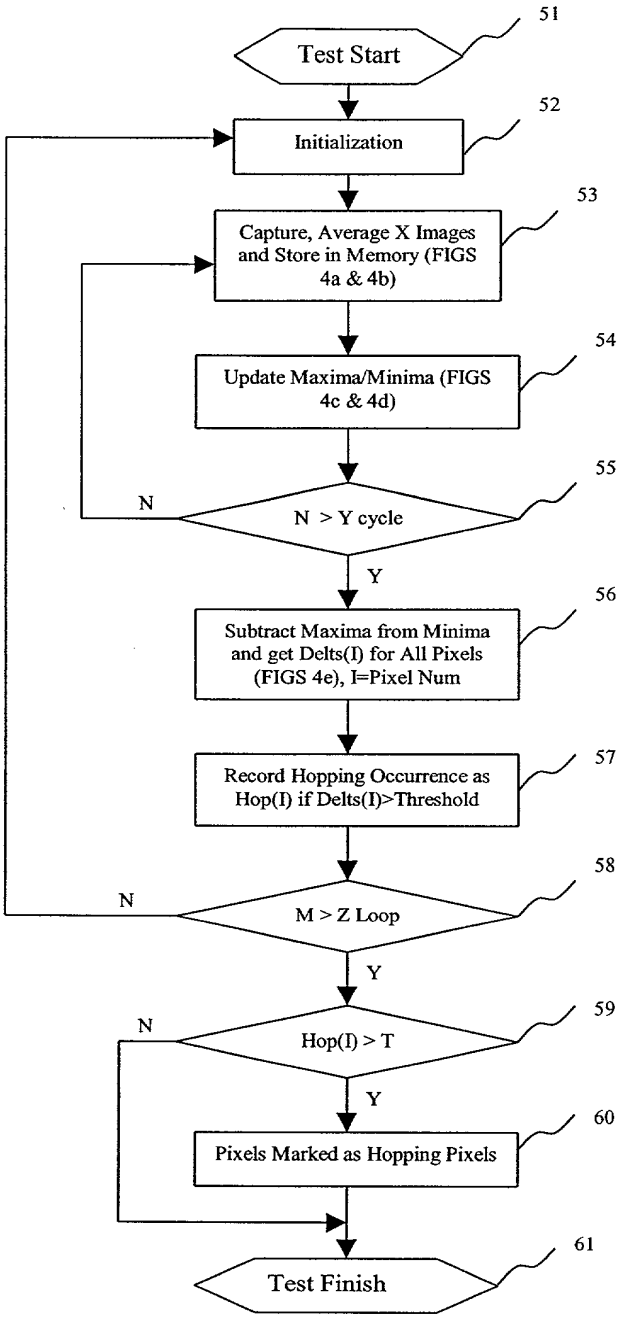
Test Start
51
Initialization
52
Capture, Average X Images and Store in Memory (FIGS 4a & 4b)
53
Update Maxima/Minima (FIGS 4c & 4d)
54
N > Y cycle
55
N
Y
Subtract Maxima from Minima and get Delts(I) for All Pixels (FIGS 4e), I=Pixel Num
56
Record Hopping Occurrence as Hop(I) if Delts(I)>Threshold
57
M > Z Loop
58
N
Y
Hop(I) > T
59
N
Y
Pixels Marked as Hopping Pixels
60
Test Finish
61

FIG. 3

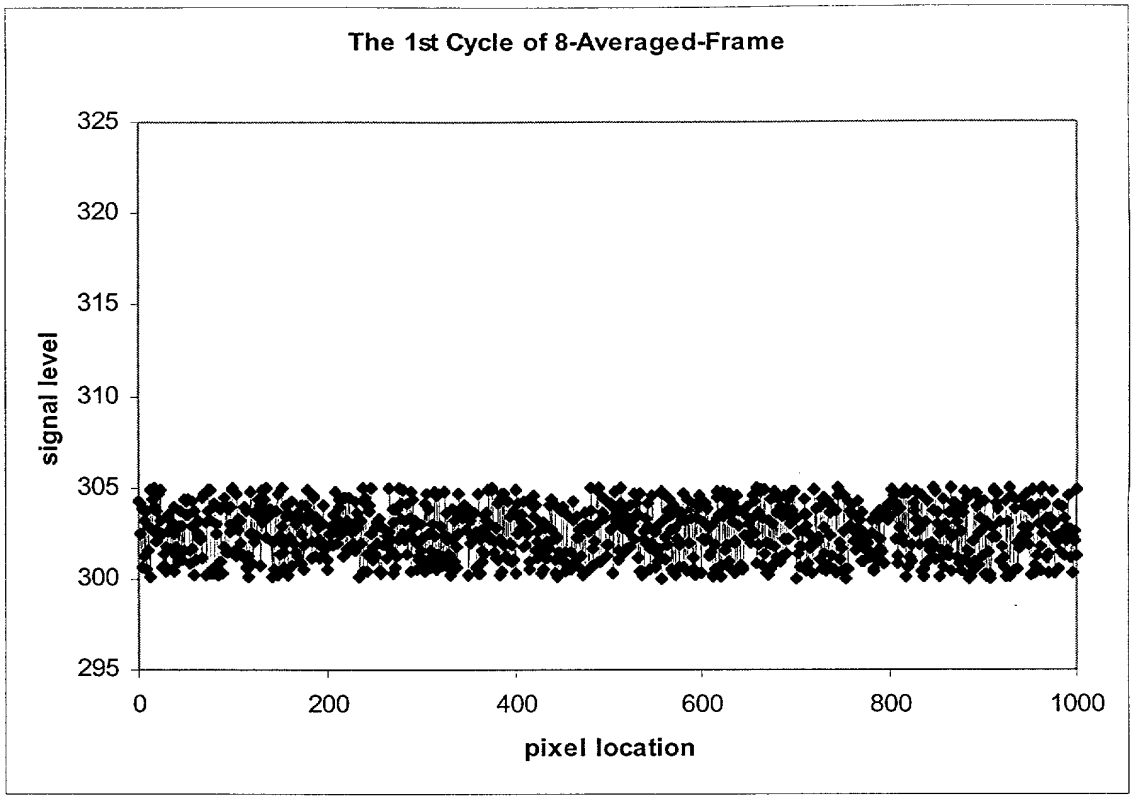
The 1st Cycle of 8-Averaged-Frame
325
320
315
310
305
300
295
signal level
0
200
400
600
800
1000
pixel location

FIG. 4a

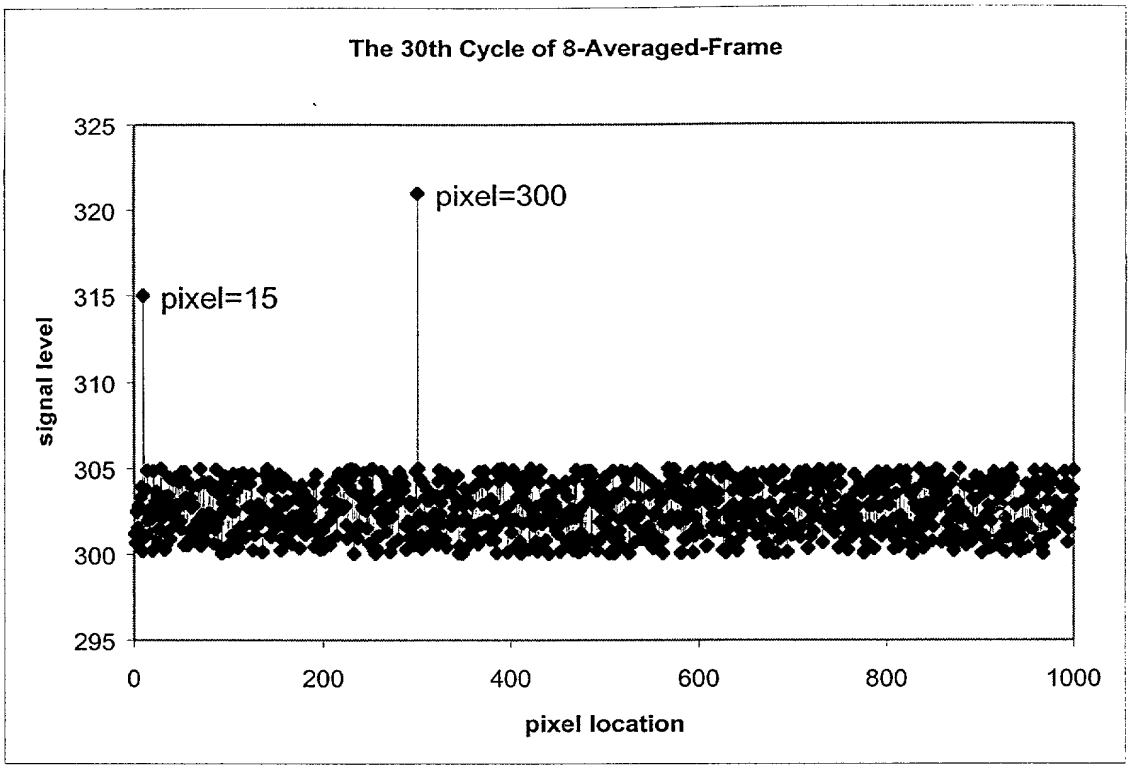
The 30th Cycle of 8-Averaged-Frame
325
320
315
310
305
300
295
signal level
pixel=300
pixel=15
0
200
400
600
800
1000
pixel location

FIG. 4b

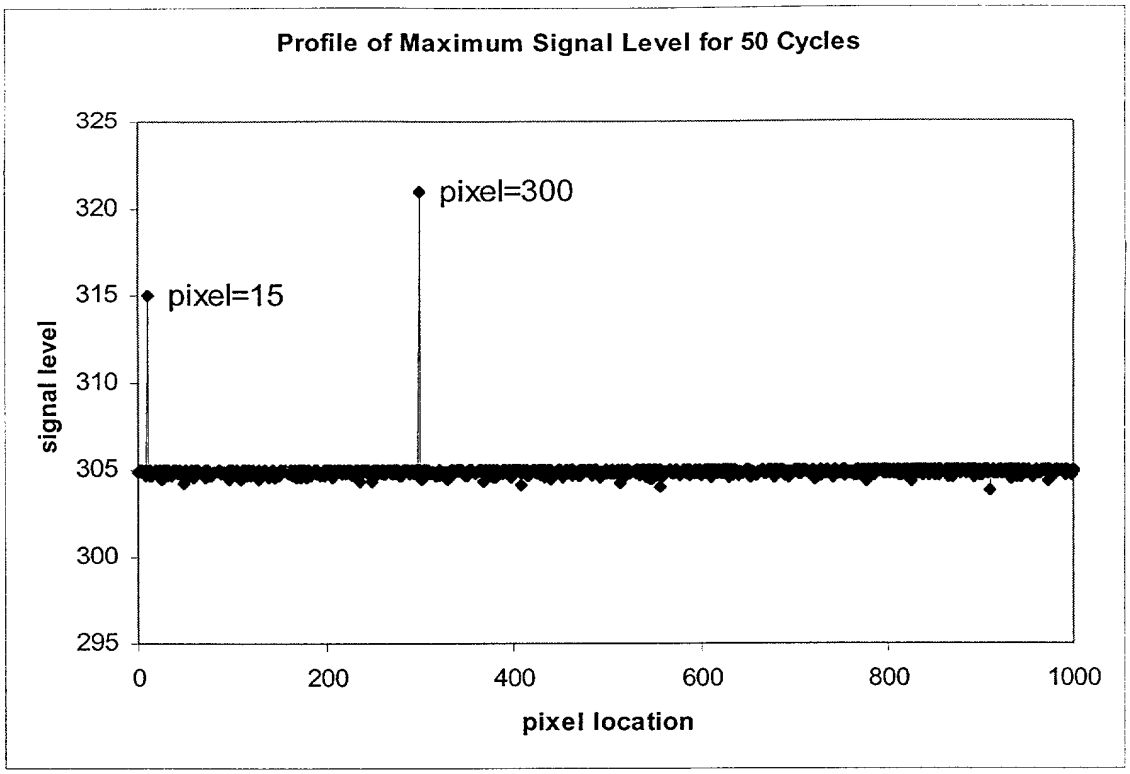
Profile of Maximum Signal Level for 50 Cycles
325
320
315
310
305
300
295
signal level
pixel=300
pixel=15
0
200
400
600
800
1000
pixel location

FIG. 4c

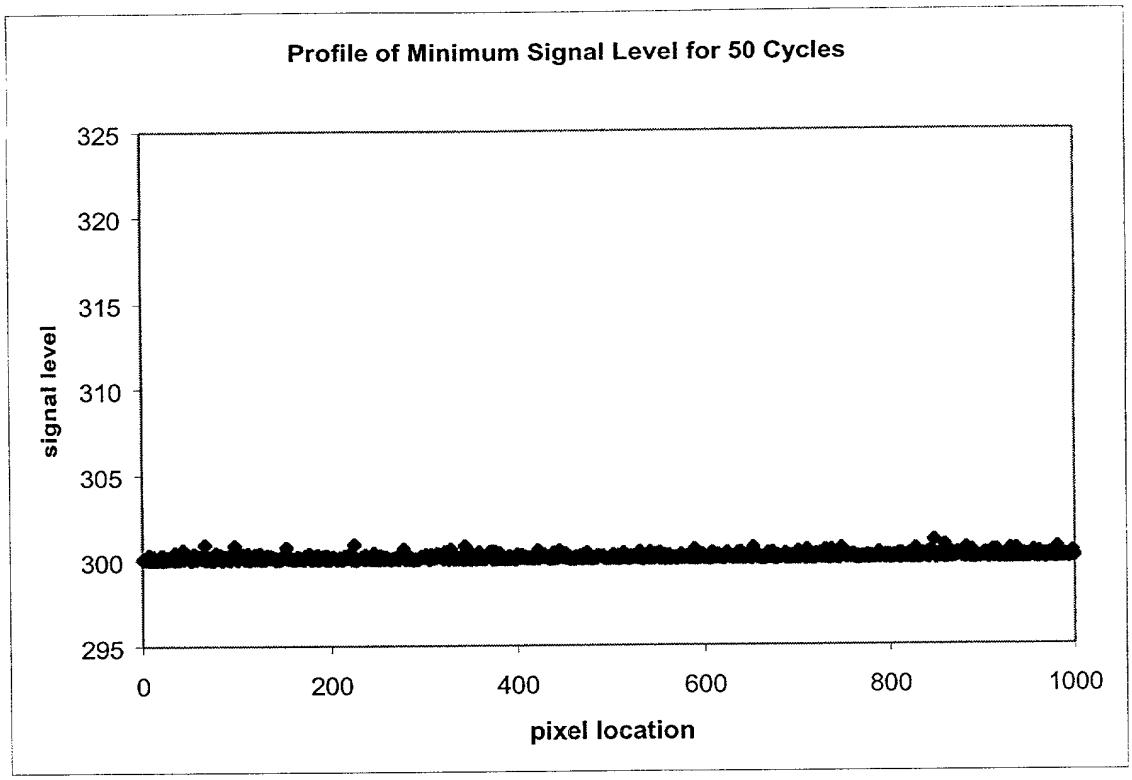
Profile of Minimum Signal Level for 50 Cycles
325
320
315
310
305
300
295
signal level
0
200
400
600
800
1000
pixel location

FIG. 4d

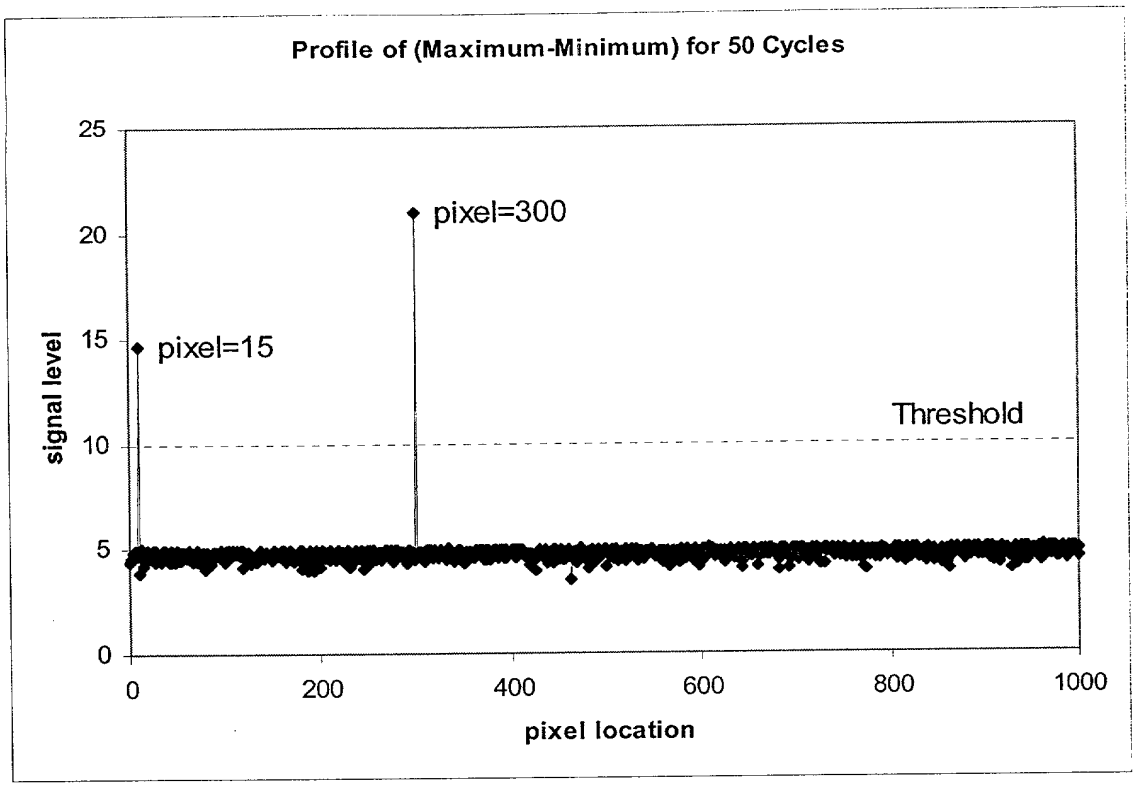
Profile of (Maximum-Minimum) for 50 Cycles
25
20
15
10
5
0
signal level
pixel=300
pixel=15
Threshold
0
200
400
600
800
1000
pixel location

FIG. 4e

Combined Declaration For Patent Application and Power of Attorney	ATTORNEY DOCKET 81229RLO

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

DETECTING HOPPING PIXEL DEFECTS IN CCD IMAGE SENSORS

The specification of which (check only one item below):

[X] is attached hereto.

[ ] was filed as United States Application Serial No. on and was amended on (if applicable).

[ ] was filed as PCT international application Number on and was amended under PCT Article 19 on (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the U.S. Patent & Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign applications(s) for patent or inventor's certificate or any PCT international application(s) designating a least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (if PCT, indicate PCT)	APPLICATION NUMBER	DATE OF FILING (day month year)	PRIORITY CLAIMED UNDER 35 USC §119			
				YES		NO
				YES		NO
				YES		NO

I hereby claim the benefit under Title 35, United States Code, 119 §(e) of any United States provisional application(s) listed below:

PRIOR PROVISIONAL APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. §119 (e):

PROVISIONAL APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under Title 35, United States Code, §120 of any prior United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior applications(s) in the manner provided by the first paragraph of Title 35, §112, I acknowledge the duty to disclose to the U.S. Patent & Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56, which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR US APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S FOR BENEFIT UNDER 35USC§120:

U.S. APPLICATIONS		STATUS (Check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.				
PCT APPLICATION NO.	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)		

Combined Declaration For Patent Application and Power of Attorney *(Continued)*	ATTORNEY DOCKET 81229RLO

POWER OF ATTORNEY: As a named inventor, I hereby appoint the attorney(s) and/or agent(s) associated with Eastman Kodak Company Customer No. 01333 to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Send Correspondence to:	Direct Telephone Calls to: *(name and telephone number)*
Patent Legal Staff Eastman Kodak Company 343 State Street Rochester, NY 14650-2201	Raymond L. Owens (716) 477-4653 FAX: (716) 477-4646

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2	FULL NAME OF INVENTOR	FAMILY NAME Carducci	FIRST GIVEN NAME Thomas	SECOND GIVEN NAME R.
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2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
3	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)
2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
4	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)
2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
5	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)
2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
6	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
[signature]	[signature]	
DATE 8/23/00	DATE 8/23/00	DATE
SIGNATURE OF INVENTOR 204	SIGNATURE OF INVENTOR 205	SIGNATURE OF INVENTOR 206
DATE	DATE	DATE